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## Lesson 9: Conditional Probabilities - Study Notes

Slide 1:

### Independent Probability

**Overview:** Events are said to be **independent** if, and only if, the occurrence of one does not affect the probability of the occurrence of the other. In other words, if event A and B are independent, then the probability of B remains unchanged regardless of the occurrence (or not) of A.

For example, when rolling two dice (A and B), the fact that die A has rolled a "5" has no effect on the result of die B.

When events are independent, the following applies:

$$P(A \text{ and } B) = P(A) \times P(B)$$

A lack of independence would imply that the result of one event had some sort of impact on the other.

Slide 2:

### Independent Probability (Cont'd)

#### Example 1:

Please determine the following probability when rolling 2 dice simultaneously:

- Rolling a **combined sum** of "4".
- Rolling a sum of "4" given that the first die shows a "3".
- Rolling a sum of "4" given that the first die shows a "5".
- Rolling a "2" with both rolls.
- Rolling a "2" with either roll.

#### Sample Space:

(1,6)	(2,6)	(3,6)	(4,6)	(5,6)	(6,6)
(1,5)	(2,5)	(3,5)	(4,5)	(5,5)	(6,5)
(1,4)	(2,4)	(3,4)	(4,4)	(5,4)	(6,4)

(1,3)	(2,3)	(3,3)	(4,3)	(5,3)	(6,3)
(1,2)	(2,2)	(3,2)	(4,2)	(5,2)	(6,2)
(1,1)	(2,1)	(3,1)	(4,1)	(5,1)	(6,1)

Show Answer

### Answers:

- Since the rolls are independent of each other, we must consider the different ways we can get a total of 4: (1 and 3, 2 and 2, 3 and 1). There are a total of 36 possible outcomes, each with an equal chance of occurring. Therefore, the probability of rolling a combined sum of "4" is 3 out of 36 ( $3/36 = 8.33\%$ ).
- Since the rolls are independent, the fact that we rolled a "3" with the first die does not affect the second roll. However, if we want a combined sum of 4, then the result of the first roll is very important. If we know in advance that our first roll was a "3", then the only way we can roll a combined sum of 4 is if we roll a "1" with the second die. The chances of doing that are 1 out of 6 ( $1/6 = 16.67\%$ ).
- If the first die registers a "5", then it is impossible for the combined sum to be "4". Therefore, the probability of rolling a combined sum of 4 given that our first roll was a 5 is 0%.
- Rolling a "2" with both dice would use the multiplication rule. In this case, if A is rolling a "2" with the first die, and B is rolling a "2" with the second one, then:  $P(A \text{ and } B) = P(A) \times P(B) = 1/6 \times 1/6 = 1/36 = 2.78\%$ .
- Rolling a "2" on either die would employ the addition rule for independent events:  $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$ . Filling in the blanks:  $1/6 + 1/6 - 1/36 = 30.56\%$ .

### Slide 3:

## Independent Probability (Cont'd)

Two events A and B are said to be independent if and only if either:

$$P(A | B) = P(A)$$

or

$$P(B | A) = P(B)$$

Two events are said to be **independent** if the occurrence or non-occurrence of one of the events does not change the probability of the occurrence of the other event. If  $P(A|B) = P(A)$  (independent), then  $P(B|A)$  will also equal  $P(B)$ . Similarly, if  $P(A|B)$  and  $P(A)$  are unequal (dependent), then  $P(B|A)$  and  $P(B)$  will also be unequal.

Otherwise, the events are said to be dependent (**conditional**).

### Example 1:

- Let A be the event that you toss a coin and get heads.
- Let B be the event that you roll a die and get "3".

- $P(A) = 1/2$
- $P(B) = 1/6$

Does the probability of getting a heads change knowing that you've already rolled a "3" with your die? Of course not! The two events do not affect each other (they are independent). This means that  $P(\text{getting heads given you've rolled a 3}) = P(\text{getting heads}) = 1/2$ .

**Note:** Order is important here.  $P(A|B)$  is not the same thing as  $P(B|A)$ . The first notation is asking what is the probability of event A given that B has occurred and the second notation is asking what is the probability of event B given that A has occurred.

### Example 2:

Drowning is the fifth most common accidental death. The chance that someone will die by drowning is 1.5 people per 100,000. The death rate for drowning by workers in the fishing industry is 86.4 per 100,000. Are the events "drowning" and "working in the fishing industry" independent events?

### Solution:

- Let A be the event of drowning.
- Let B be the event of being employed as a fishing person.
- $P(A) = 1.5/100,000 = 0.000015$
- $P(A|B) = 86.4/100,000 = 0.000864$

Since 0.000015 does not equal 0.000864, the events "drowning" and "working in the fishing industry" are not independent.

### Slide 4:

## Conditional Probability

You are playing the famous "Go Fish" card game with a friend. The object of this game is to assemble as many pairs as possible by either selecting cards from the pile, or by asking your opponent for a card you need. There are 20 cards left in the pile and it's your turn. You are trying to get rid of the ace in your hand and ask your friend if she has an ace in hers. Unfortunately, she doesn't and tells you "go fish" (select a card). If you are holding the only ace that has been selected to date, there should be 3 more in the pile ( $3/20 = 0.15$ ), thus giving you a 15% chance of selecting one. But if a pair of aces has already been put together, the chances of selecting the remaining ace will be different ( $1/20 = 5\%$ ). This is an example of conditional probability.

**Overview:** Conditional probability is the evaluation of an event in a space that is smaller than the original sample space. **Two events are often related so that the probability of the occurrence of one depends on whether the second has or has not occurred.** Conditional probability therefore encompasses dependent events.

For example, suppose that one experiment consists of observing the weather on a specific day. Let A be the event "observe rain" and B be the event "observe dark clouds." Event A and B are related. The probability of rain  $P(A)$  is not the same as the probability of rain given prior information that the sky contains dark clouds. The probability of A,  $P(A)$ , would be the fraction of the entire population of observations that result in rain.

Slide 5:

## Conditional Probability (Cont'd)

Now let us look only at the subpopulation of observations that result in B (dark, cloudy day) and the fraction of these that result in A. This fraction, called the **conditional probability**, describes the probability of A given that B has occurred, and is denoted as  $P(A|B)$ .

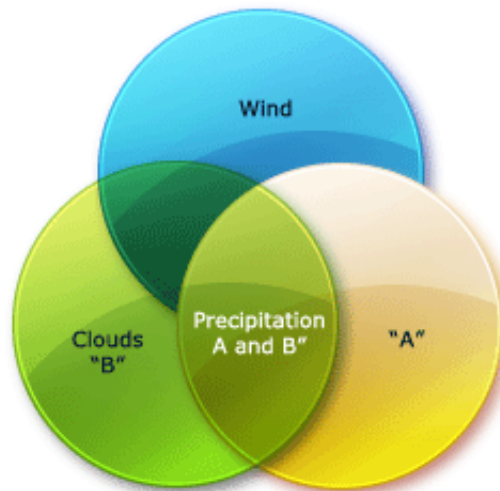
$$P(A|B) = \frac{P(A \text{ and } B)}{P(B)} \text{ and } P(B) \neq 0$$

$$P(B|A) = \frac{P(B \text{ and } A)}{P(A)} \text{ and } P(A) \neq 0$$

Note: The vertical bar, like the one in  $P(A|B)$ , is read "given that", meaning that the probability of event A, given that event B has occurred, is...

By attaching some numbers to the probabilities in the weather example, we can see that this definition of conditional probability is consistent with the relative concept of probability. Recall that A denotes rain on a given day (precipitation) and B denotes that the day is cloudy (clouds). Now suppose that 10 percent of all days are rainy and cloudy [i.e.,  $P(A \text{ and } B) = 0.10$ ] and 30 percent of all days are cloudy [ $P(B) = 0.30$ ].

Mother Nature's Toys



$$P(A|B) = \frac{0.10}{0.30} = 33.33\%$$

The probability of a rainy day, given that it's cloudy, is 33.33%.

Slide 6:

## Conditional Probability from Tables

Sample for University Enrolment in Biology

University	Male	Female	Total

McGill	227	208	435
Concordia	309	331	640
<b>Total</b>	<b>536</b>	<b>539</b>	<b>1075</b>

### Example 1:

If we randomly select a student from our sample, what are the chances that they are:

1. From Concordia?
2. Female?
3. Male, given that they are from McGill?
4. From Concordia, given that they are female?

#### Answers:

1.  $P(\text{Concordia}) = \# \text{ Concordia students} / \text{total} \# \text{ students} = 640 / 1075 = \mathbf{0.5953, \text{ or } 59.53\%}$
2.  $P(\text{female}) = \# \text{ females} / \text{total} \# \text{ students} = 539 / 1075 = \mathbf{0.5014, \text{ or } 50.14\%}$
3.  $P(\text{male}|\text{McGill}) = P(\text{Male and McGill}) / P(\text{McGill}) = 227 / 435 = \mathbf{52.18\%}$
4.  $P(\text{Concordia}|\text{female}) = P(\text{Concordia and female}) / P(\text{female}) = 331 / 539 = \mathbf{61.41\%}$

#### Slide 7:

### The Multiplication Law

Given two events A and B, the probability of the intersection AB is:

$$P(\mathbf{A \text{ and } B}) = P(\mathbf{A}) \times P(\mathbf{B | A})$$

or

$$P(\mathbf{B \text{ and } A}) = P(\mathbf{B}) \times P(\mathbf{A | B})$$

Note: This version of the Multiplication Rule is just the rearrangement of the Conditional Probability Rule, where  $P(B|A) = P(A \text{ and } B)/P(A)$ . Also, recall that  $P(A \text{ and } B)$  is just the intersection or overlap of events A and B.

Unless A and B are independent, in which case:

$$P(\mathbf{B | A}) = P(\mathbf{B}) \text{ so} \\ P(\mathbf{A \text{ and } B}) = P(\mathbf{A}) \times P(\mathbf{B})$$

### Example 1:

A teacher of a group of 20 students wants to get the opinion of 2 of the students (to be selected at random) about the website [www.math.com](http://www.math.com). If 12 of them approve of the website and the

other 8 are against it, what is the probability that both of the students chosen by the teacher will be against the new website.

**Answer:** Assuming equal probabilities for each selection (which is what we mean by the selection being random), the probability that the first student selected will disapprove of the website is  $8/20$ . The probability that the second student selected will be against the website, given that the first one shares their opinion, is  $7/19$ . Thus, the desired probability is  $(8/20) * (7/19) = 14/95$  (**14.73%**).

These are NOT INDEPENDENT events because there is a **limited number** of students and the probability of selecting a 2nd student against the website decreases from 40% to 36.8% after the first student has been selected.

Using the formula:

$P(\text{1st student against and 2nd against}) = P(\text{1st student against}) \times P(\text{2nd against given 1st against})$

$P(A \text{ and } B) = P(A) \times P(B|A)$

Slide 8:

## With Replacement vs. Without Replacement

### Overview:

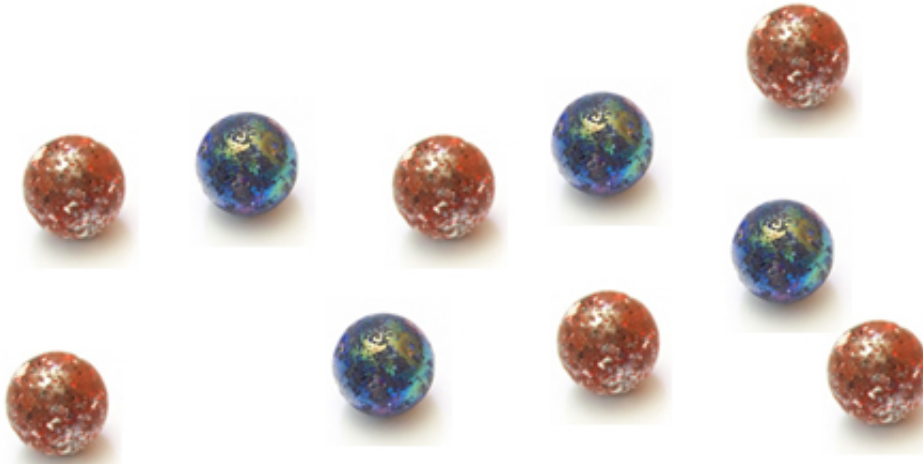
When dealing with random selection probability questions (pick a card from a deck of cards, pick a coloured marble from a bag, etc.) we must specify if the object is being put back after being selected or not. When the population is small, this is very important information because each pick can be affected by previous results. In probability experiments that specify **replacement**, it means that the selected object is put back into the sampling space after it has been selected. Therefore, the probability of selecting it again, or any other object for that matter, remains unchanged. However, in probability problems that are **without replacement**, each selection has a direct effect on subsequent selections since the sample space is reduced.

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## With Replacement vs. Without Replacement (Cont'd)

### Example 1:

If we had a bag of 10 marbles (6 red and 4 blue), the probability of reaching in and pulling out a red marble would be  $(6 / 10) = 60\%$ , whereas selecting a blue one would be  $(4 / 10) = 40\%$ .



Now let's say that we wanted to figure out the probability of selecting 3 red marbles in a row. There are two ways to complete this problem, and we will investigate both of them:

### With Replacement:

If we are replacing each draw (after picking a red marble, we put it back into the bag and choose again), then the probabilities of selecting a red marble stay the same throughout the problem. This means that the chances of selecting 3 red marbles in a row are:

$$(6 / 10) \times (6 / 10) \times (6 / 10) = 27 / 125 = \mathbf{21.6\%}.$$

### Without Replacement:

When we do not replace the objects we have selected, the sample size (10) will be reduced by one after each draw. Furthermore, the number of red marbles in the bag will also decrease by one. For example, the probability of selecting 3 red marbles in a row will be:

1st red marble: **6 / 10** (60%).

2nd red marble: **5 / 9** (55.56%) since one red marble has already been removed from the bag.

3rd red marble: **4 / 8** (50%) since two red marbles have already been removed from the bag.

Total:  $(6 / 10) \times (5 / 9) \times (4 / 8) = 1 / 6$   
**(16.67%).**

\*Notice that as we select a red marble, the probability of selecting another one will decrease, but the chances of selecting a blue one (which were 40%) will increase. Give it a try!\*

Slide 10:

## With Replacement vs. Without Replacement (Cont'd)

### Example 2:

Two cards are drawn at random from an ordinary deck of 52 playing cards. What is the

probability of getting two aces if:

- The first card is replaced before the second card is drawn? (**probability with replacement**)
- The first card is not replaced before the second card is drawn? (**probability without replacement**)

**Answer:**

- Since there are four aces among the 52 cards, we get  $(4/52)*(4/52) = 1/169$ .
- Since there are only three aces among the 51 cards which remain after one ace has been removed from the deck, we get  $(4/52)*(3/51) = 1/221$ .

### Example 3:

If  $P(A) = 0.65$ ,  $P(B) = 0.40$ , and  $P(A \text{ and } B) = 0.24$ , are the events A and B independent?

**Answer:** Since  $P(A) * P(B) = (0.65) (0.40) = 0.26$  and not 0.24, **the two events are not independent.**

Slide 11:

## Applying the Conditional Probability Formula

The general multiplication rules are useful in solving many problems in which the ultimate outcome of an experiment depends on the outcomes of various intermediate stages. The trick is to modify the conditional probability formula in a way that will deal directly with the problem at hand. There are several ways to tackle such problems:

**(i) using a tree diagram**

**(ii) applying the conditional probability formula**

**(iii) via a tabular format**

The method you choose will depend on the complexity of the problem, as well as your familiarity with each technique. Let's take a look at a generic problem and attempt to solve it using the three methods:

### Example 1:

Bright Idea Inc. is an electronics company that specialises in the manufacturing of light bulbs. On average, 8% of the light bulbs it produces are defective. Therefore, the products are inspected before being distributed. The inspectors who examine the bulbs tend to misclassify them 10% of the time. That is, they classify good bulbs as being defective, and defective bulbs as good ones 10% of the time. What proportion of the light bulbs inspected will be classified as "good"?

Slide 12:

## i. Using the Tree Diagram

Let's identify the possibilities with the following symbols:

G = light bulb is good

D = light bulb is defective

CG = light bulb has been classified as "good" by the inspectors

CD = light bulb has been classified as "defective" by the inspectors

For our purposes, we are interested in determining the probability that a light bulb will be classified as being "good" (CG). Not only does this include the bulbs that actually work, but due to error, this also includes defective bulbs. In other words:

$$CG = [(G)(CG | G)] + [(D)(CG | D)]$$

$$CG = (G \text{ and } CG) + (D \text{ and } CG)$$

$$CG = (0.92)(0.90) + (0.10)(0.08)$$

$$CG = 0.828 + 0.008$$

$$CG = 0.836$$

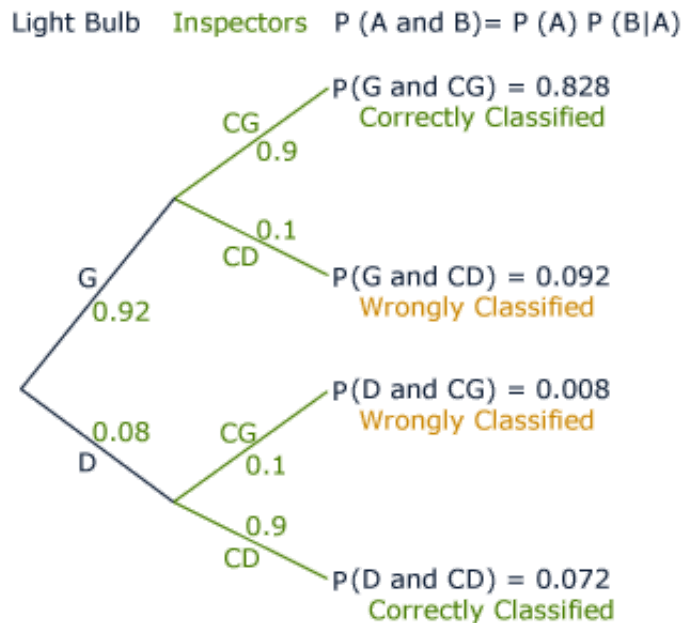
8% are defective, 92% are good and 90% are properly classified and 10% of the defective bulbs are classified as good out of the 8% that are defective.)

This means that **83.6%** of the bulbs produced will be classified as "good", even if they don't all deserve to be!

That brings up another question. Of the bulbs that have been classified as "good", how many actually are?

To solve this problem, we must divide the proportion of bulbs that have been correctly classified as "good" (G) by the total number that the inspectors approved (CG).

$$\begin{aligned}
 P(G|CG) &= \frac{P(G \text{ and } CG)}{P(CG)} \\
 &= \frac{P(G) \times P(CG|G)}{[P(G) \times P(CG|G) + P(D) \times P(CG|D)]} \\
 &= \frac{0.828}{0.828 + 0.008} = \mathbf{0.9904}
 \end{aligned}$$



**Therefore, 99% of the light bulbs that are classified as good are actually good.**

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## ii. Applying the Conditional Probability

Formula

The calculation that we just completed is in fact the product of Bayes' Theorem. The Reverend Thomas Bayes (1702-1761), an English Presbyterian minister who doubled as a mathematician in his spare time, was the first to develop an expanded form for conditional probability. It is with this equation that we can dynamically revise and adjust probabilities assigned to specific events as new information is made available to us. The generalised formula is as follows:

$$P(A_k|B) = \frac{P(A_k) \times P(B|A_k)}{\sum [P(A_i) \times P(B|A_i)]}$$

where  $P(A_k | B)$  is the probability of a specific event given that B has occurred, and  $A_i$  represents the set of all possible outcomes given the occurrence of B.

If we apply this formula to our previous example involving the light bulbs, we would first identify the probability we want to find. In our case, we want to determine the probability that a light bulb that has been classified as being good (CG) actually is (G). In other words, we want to determine:

$$P(G | CG)$$

According to Bayes' Theorem:

$$P(G|CG) = \frac{P(G) \times P(CG|G)}{\sum [P(G_i) \times P(CG|G_i)]}$$

$$P(G|CG) = \frac{P(G) \times P(CG|G)}{[P(G) \times P(CG|G) + P(D) \times P(CG|D)]}$$

$$P(G|CG) = \frac{0.92 \times 0.9}{(0.92 \times 0.9) + (0.08 \times 0.1)}$$

$$P(G|CG) = 0.9904$$



Slide 14:

### iii. Tabular Format

The conditional probability question can also be solved via a simplified tabular format. To start, one must identify the information that is given to us:

align="center" cellPadding=0 cellSpacing=0 bordercolor="#063763" id="tableData">

	<b>1</b>	<b>2</b>	<b>3</b>
	<b>Possibilities (Ai)</b>	<b>P (Ai)</b>	<b>P (B   Ai)</b>
A1	Item is good	0.92	0.9
A2	Item is defective	0.08	0.1
<b>At</b>	<b>Total</b>	<b>1.00</b>	style="TEXT-ALIGN: center">

B, in this case, represents the fact that the item was classified as being good. We then expand the table by multiplying columns 2 and 3 to produce a fourth column labeled:

$P(A_i) \times P(B | A_i)$ . This column represents the probability of  $A_i$  and B.

align=center cellPadding=0cellSpacing=0 bordercolor="#063763" id="tableData">

	1	2	3	4
	Possibilities ( $A_i$ )	P ( $A_i$ )	P (B   $A_i$ )	P ( $A_i$ ) x P(B   $A_i$ )
A1	Item is good	0.92	0.9	0.828
A2	Item is defective	0.08	0.1	0.008
<b>At</b>	<b>Total</b>	<b>1.00</b>		<b>P(B) = 0.836</b>

Therefore, according to our table, 82.8% of the items will be good and classified as being good, and 0.8% as being defective, but classified as being good.

The sum of column 4 represents P (B), or the probability that the light bulb will be classified as being good. This value (0.836) is very important for the last step, which involves the creation of a last column that will represent the final, conditional probabilities,  $P(A_i | B)$ . We get this last column by dividing the values in column 4 by the sum of that column. In other words, 0.828 divided by 0.836 for  $P(A1 | B)$ , and 0.008 divided by 0.836 for  $P(A2 | B)$ .

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	1	2	3	4	5
	Possibilities ( $A_i$ )	P ( $A_i$ )	P (B   $A_i$ )	P ( $A_i$ ) x P(B   $A_i$ )	P ( $A_i   B$ )
A1	Item is good	0.92	0.9	0.828	0.9904
A2	Item is defective	0.08	0.1	0.008	0.0096
<b>Ai</b>	<b>Total</b>	<b>1.00</b>		<b>P (B) = 0.836</b>	<b>1.0000</b>

Therefore,  $P(A1 | B)$  is **0.9904**, meaning that **99.04%** of the items classified as good actually are. On the other hand,  $P(A2 | B)$  represents the probability that an item is defective given that it has been wrongly classified as being good, 0.96%.

Please note that columns 2 and 5 must always add up to 1. Although column 3 adds up to 1 in this situation, it is not always the case (especially when dealing with **false positives**).

Slide 15:

## Bayes' Theorem - False Positives

Bayes' Theorem also applies to situations where we encounter false positives. A false positive is a misdiagnosis caused either by human or mechanical error that is usually uncontrollable. For example, athletes are asked to provide multiple urine samples during banned-substance testing. Each sample is tested individually in case of error. If all the samples yield identical results, then the verdict is accepted. Imagine accusing an Olympic athlete of anabolic steroid use only to find that your tests were in error!



## Exercises: Conditional Probability

### Problem 1:

The table below shows the probabilities of males (M) and females (F) being employed (E) or unemployed (U) in some population (it excludes those not wishing to be employed).

align="center" cellpadding="0" cellspacing="0" bordercolor="#063763" id="tableData">

	<b>M</b>	<b>F</b>	
<b>E</b>	0.52	0.41	0.93
<b>U</b>	0.05	0.02	0.07
	0.57	0.43	>1.00

Please find:

- The conditional probability of employment given that the person is male  $P(E | M)$ .
- The conditional probability of being male given that the person is employed  $P(M | E)$ .

Show Answer

**Answer:**

$$P(E|M) = \frac{P(E \text{ and } M)}{P(M)} = \frac{0.52}{0.57} = 0.91$$

$$P(M|E) = \frac{P(M \text{ and } E)}{P(E)} = \frac{0.52}{0.93} = 0.56$$

As you noticed, you can take the numbers directly off the table if they are available.

Slide 17:

## Exercises: Conditional Probability (Cont'd)

### Problem 2:

You are in charge of raising funds for your graduating class. Traditionally, the main fundraiser has been selling boxes of oranges to the general public. The two companies that supply the oranges, Ola Oranga and O-Fruity, have been known to deliver some rotten specimens in the past. Of the cases of oranges you have ordered, 65% are from Ola Oranga and 35% come from O-Fruity. There's a 2% chance that a randomly-chosen orange will be rotten from the Ola Oranga crate, and a 5% chance of bad fruit from O-Fruity's box. If the boxes are unmarked and an orange chosen at random is found to be rotten, what are the chances of it coming from the Ola Oranga company?

Show Answer

**Answer:**

align="center" cellpadding="0" cellspacing="0" bordercolor="#063763" id="tableData">

<b>P(A)</b>	Ola Oranga	0.65
<b>P(B)</b>	O-Fruity	0.35
<b>P(R   A)</b>	Rotten Ola Oranga	0.02
<b>P(R   B)</b>	Rotten O-Fruity	style="TEXT-ALIGN:center">0.05

We want to determine the probability that an orange is from Ola Oranga given that it is rotten.

$$P(A | R)$$

From Bayes' Theorem:

$$P(A|R) = \frac{P(A) \times P(R|A)}{P(R)}$$
$$P(R) = [P(A) \times P(R|A) + P(B) \times P(R|B)]$$
$$= \frac{0.65(0.02)}{0.65(0.02) + 0.35(0.05)}$$
$$= \frac{0.0130}{0.0305} = 0.4262$$

This means that upon finding a rotten orange, there is a **42.62%** chance that it came from Ola Oranga.

Slide 18:

## Exercises: Conditional Probability (Cont'd)

### Problem 3:

As chief of security aboard the starship Entrepreneur, you are frequently required to make critical decisions that can affect the safety of the crew. Today, you must make one of these infamous decisions. You have a weapons detector secretly installed in the entrance of the starship's nightclub, "Deep Space Disco", which can detect concealed arms 75% of the time. Unfortunately, it will sound a false alarm once for every 150 people who pass through and are not carrying weapons. An alien manufacturing firm, "Saturn Security", has developed a new detector which they claim is superior to the one currently being used. The new detector can correctly identify a weapon 90% of the time. On the other hand, it also sounds a false alarm once per 100 individuals.

From your previous experience, you know that about 5.5% of the ship's occupants carry concealed weapons. Which detector can best detect those individuals who are actually carrying

weapons when they are detected by the device?

*"Damn it, Jim! I'm a doctor, not a statistician!"*

Show Answer

**Answer:**

For this question, we must consider the probabilities for both machines (old and new).

Let  $W_i$  represent if the individual is armed or not (weapon or no weapon).

Let + indicate a positive test (alarm goes off).

**Current Device**

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Weapon	P( $W_i$ )	P(+   $W_i$ )	P(+)	P( $W_i$   +)
Weapon	0.055	0.75	0.04125	86.7%
No Weapon	0.945	0.0067	0.00633	13.3%
Total	1.0	0.7567	0.04758	100%

**Alien Device**

align="center" cellpadding="0" cellspacing="0" bordercolor="#063763" id="tableData" style="padding: 0;">>

Weapon	P( $W_i$ )	P(+   $W_i$ )	P(+)	P( $W_i$   +)
Weapon	0.055	0.90	0.0495	84.0%
No Weapon	0.945	0.01	0.00945	16.0%
Total	1.0	0.91	0.05895	100%

Where, using Bayes' Theorem:

$$P(W_i | +) = \frac{P(W_i) \times P(+ | W_i)}{P(+)} = \frac{P(W_i) \times P(+ | W_i)}{[P(W_1) \times P(+ | W_1) + P(W_2) \times P(+ | W_2)]}$$

As you can see, the current machine will successfully diagnose an individual 86.7% of the time whereas the alien device will do the same 84% of the time. Therefore, we shall stick with our

old machine.

**Slide 19:**

## **Recap**

As you have learned in this lesson, probabilities can be altered based on prior information. Namely, if a condition or event affects another, then they are deemed to be dependent, and therefore must be treated differently. In summary:

- Conditional probabilities alter the “whole” of the original calculation such that the ratio has changed.
- If the events are independent, then the condition will not change the ultimate ratio between the “part” and the “whole”.
- If this ratio is altered due to a prior condition, then the events are said to be dependent.
- Bayes’ Theorem is a procedure to calculate conditional probabilities that uses a given formula, but that can also be calculated in a tabular or graphical (tree diagram) format.

You can post a message online in your discussion folder any time you have something to share with your discussion group concerning the current lesson. Simply click [Discussion Board](#) or use the menu at the top of the screen.

**Next lesson: Probability Distributions**